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Preface

During DESERT STORM, the combatants used Tomahawk and conventional air launched cruise missiles and SCUD missiles with varying success. The Allied forces used cruise missiles against military targets such as electrical power stations and communication centers. The Iraqis used the SCUD missile as a terror weapon against Israel and Saudi Arabia.

One can trace the development of these weapons to the German vengeance weapons of World War II. The Germans used these weapons as retribution against the Allies, specifically Great Britain, for the Allied strategic bombing campaign. In this paper, I will examine the military utility of these German weapons. I will investigate the capabilities of the weapons and answer the debate whether earlier development of these weapons would have made a significant impact to World War II.

I would like to thank Dr. Richard Muller for his assistance during the development of this paper. His support, review and detailed knowledge on the subject has been an inspiration throughout the year. Additionally, I would like to thank Mr. Joe Caver of the Historical Research Agency. He helped to uncover a plethora of information contained in historical documents.

Abstract

The Tomahawk cruise missile, the conventional Air Launched Cruise missile, and the SCUD surface-to-surface missile each made an impact during the Gulf War. The cruise missiles were instrumental in incapacitating the Iraqi electrical network. The SCUD missile was not as successful, but did divert the coalition air campaign. Although never utilized, the sister of the SCUD missile, the intercontinental ballistic missile, was pivotal during the Cold War. Each of these weapons can trace their initiation to the development of the German V-1 flying bomb and V-2 rocket during World War II.

The German weapons were not as successful as their antecedents. This paper will inspect the military utility of the weapons during World War II. Initially, the paper will define the actors behind the development, and describe the resulting weapons. Next, the essay will examine the strategy in weapon utilization. The paper will quantify the damage caused by both weapons. Then, the document will describe offensive and defensive countermeasures employed by the Allies. The question of the weapons' military utility will be addressed. Finally, alternatives to the weapons development, production, and employment will be presented.

Chapter 1

Description and Technical Development

Since the enormous loss of bomber planes as a result of the attacks against England in 1940, my colleagues and I have been firmly convinced that a defeat in the air war on the western front could be prevented, if at all, only by the employment of guided missiles of very great range and effect.

—Gen. Walter Dornberger
V-2

An important aspect of understanding the development of the two German long-range weapons of World War II is the organizations orchestrating that development. The A-4, later known as the V-2 rocket, was spearheaded by the Ordnance Branch of the German Army. The Luftwaffe developed the V-1 flying bomb. Instead of a coordinated weapons development program, the High Command allowed the services to manufacture new weapons with little oversight or collaboration. More importantly, the military developed weapons with little strategic or operational vision for their eventual military use.

V-2 Rocket

Actors

Following World War I, a majority of artillery officers led the remnants of the German Army. During the war, both the Allies and the Central Powers used artillery to try to break the stalemate that developed with trench warfare. The influence of the Army's artillery branch resulted in longer-range artillery pieces sending larger shells against a well-entrenched enemy.

General Walter Dornberger. Walter Dornberger was probably the single most influential individual for the development of the V-2 rocket. He was the chief salesman, marketer, and integrator of the rocket for the military. His involvement with the rocket program has its roots during World War I where General Dornberger was an artillery officer working on the Paris Gun. Next to the airplane, the Paris Gun was the most technologically advanced weapon of World War I. The gigantic gun sat on a railroad track lobbing shells with 22 pounds of explosives over 70 miles into Paris. The hope was that the shelling would affect the morale of the French and result in a shortening of the war. Unfortunately, the gun was at the limit of artillery capability resulting in a little over three hundred shells falling on Paris. His experience with the Paris Gun foreshadowed those to come with the V-2 rocket.

Walter Dornberger was also a space enthusiast. He began to postulate with others the possibility of using rockets for military success. The Treaty of Versailles limited the ability of the Germans to conduct military research after World War I. However, the treaty did not foresee the emergence of rocket technology after the war. For Dornberger, rockets were the next horizon for artillery. Sufficient numbers of accurate rockets raining down on cities would bring the civilian populace to its knees. What had not worked with the Paris Gun would be successful with the rocket.

Dornberger stated the requirements for the rocket program using the Paris Gun as an example. The rocket must have a warhead one hundred times the Paris Gun and traverse twice the distance. General Dornberger stated the accuracy requirements in artillery terms. Fifty percent of the missiles must fall within a circle of two to three "mils"—0.2 to 0.3 percent of total range. After traveling 200 miles, the rocket must be within a half a mile approximately. The final requirement was that the missile body must be transportable and fit within a standard European railroad tunnel.[1]

During World War II, General Dornberger would become the passionate advocate for the development and production of the rocket. He personally lobbied Albert Speer, Director of Armaments, and Adolf Hitler for increased priority. He championed program successes and downplayed delays resulting in Hitler conferring the highest priority for the program by 1943. The V-2 would not have finished development, besides reached production, without the General's constant dedication.

Werner von Braun. The next most influential individual during the development of the V-2 was Werner von Braun. Von Braun was from an aristocratic family in Germany. Like General Dornberger, he shared an interest in space flight. He joined the rocket team in the early 1930's while in his early twenties. Von Braun was the brains behind the technology that would make the V-2 a success. He oversaw the infancy of the liquid rocket program. His influence increased during the successes and successful "failures" of the A-1 through A-3.

Werner von Braun was instrumental in solving the three biggest technical obstacles facing the A-4. These obstacles were the development of the missile gyroscope, high speed aerodynamics, and rocket engine development. Although, the Germans shrouded the rocket development in secrecy, von Braun was able to incorporate the work of scientists throughout Germany. He basically taught himself aerospace engineering throughout the development of the rocket.

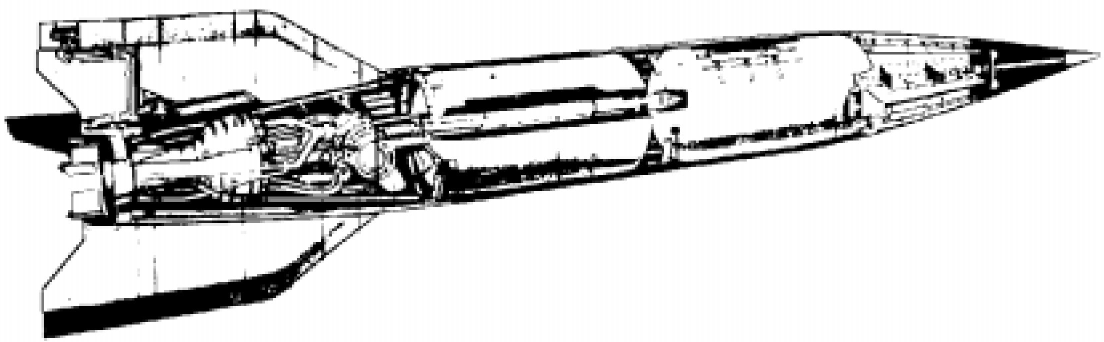
After the war ended, Werner von Braun brought his knowledge from the rocket program to the United States. His assistance plus his staff initiated the American military rocket programs and the National Aeronautics and Space Administration (NASA). His work resulted in the successful launch of astronauts to the moon, thereby satisfying a lifelong dream of space flight.

Werner von Braun was more than just a space enthusiast. While his contributions to NASA are immeasurable, von Braun also proudly served Germany. Although he did not initiate the use of slave laborers at the production facilities at Peenemunde and Mittelwerk, he did not press to discontinue their use. He continued to devote his time in solving the technical hurdles that befell the program. His expertise was pivotal in the deployment of the rocket during World War II.

Missile Description

Eventually, the V-2 surpassed most of its technical and bureaucratic (service and government agency rivalry) obstacles. The final product was a 46-foot tall rocket with a dry weight of almost 9,000 pounds and a warhead of over one ton (see Figure 1).

Launch crews would transport the rocket on a Meillerwagen (a trailer used to transport, erect, and launch the V-2) to the launch site. Once at the site, the crews would elevate the missile to vertical launch position. Final checks and gyroscope alignment would occur before launch. Once launched, the engine would mix alcohol (derived from potatoes) and liquid oxygen to propel the rocket to an apex of 50 miles. After approximately sixty seconds, the engine would stop. During the climb, the rocket would pitch to 45° and continue to the target. Approximately 200 miles down range and five minutes after launch, the V-2 would impact the target area. The rocket would impact with supersonic velocity with little warning to the inhabitants. (See Appendix A for further rocket specifications)



Source: US Strategic Bombing Survey, *Aircraft Division Industry Report* (2nd edition, January 1947), no page marked

Figure 1. V-2 Rocket

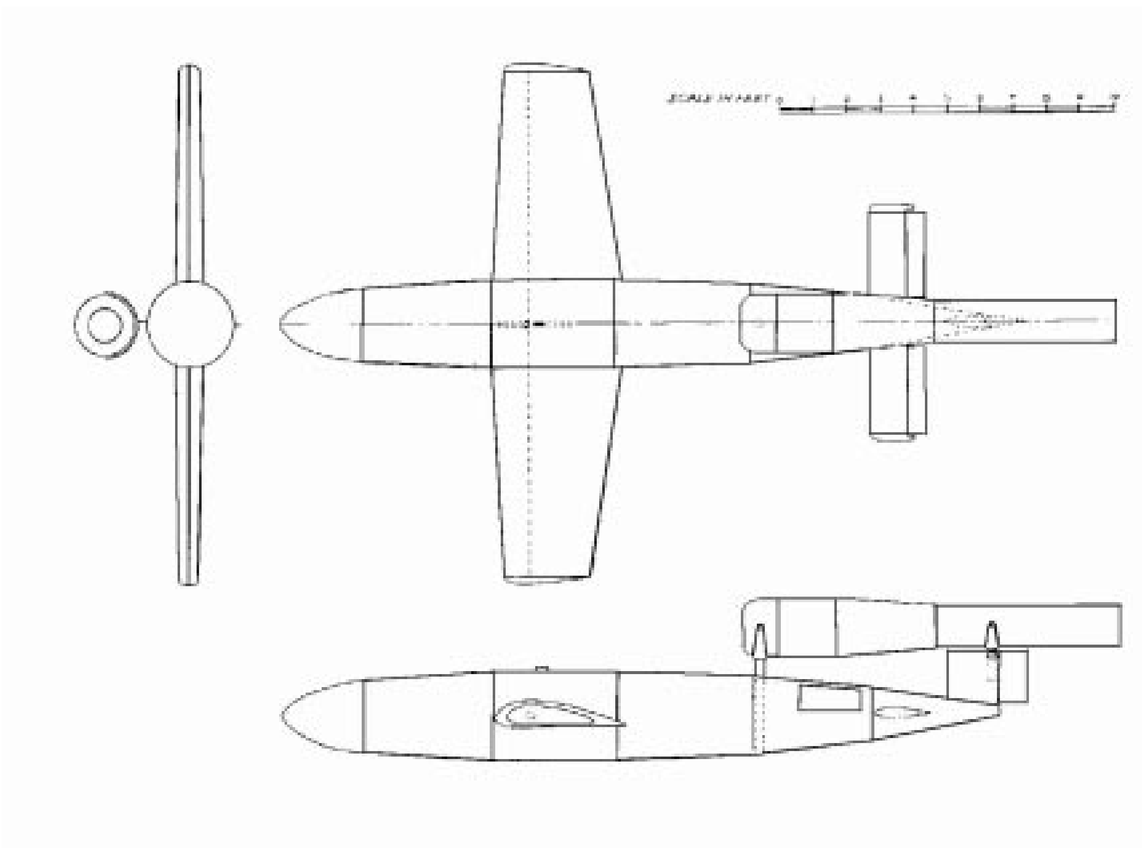
V-1 Flying Bomb

The Luftwaffe developed the V-1 Flying bomb, or "Buzz" bomb. After the disastrous performance by the Luftwaffe during the Battle of Britain, the army rocket program gained in priority. The Luftwaffe was jealous of the extra attention given to the Ordnance branch. They felt that the rocket should be a Luftwaffe program anyway. In order to regain some respect, the service developed an inexpensive alternative in the long range weapon race.

While the V-2 had all the thrills and technology behind its design, the V-1 was simple in comparison. Its low cost was due to a simple airframe of thin steel skin with a proven pulse jet engine. Probably the most complicated aspect of the missile was the launching mechanism. A catapult would accelerate the flying bomb to 230 miles per hour over a 150-foot track.

Description

The V-1 looked like a small airplane with no cockpit. Above and to the rear of the missile was the externally mounted, stovepipe engine (see Figure 2). The total length was just over 25 feet with a wing span of 17.5 feet. The normal version of the "buzz" bomb weighed almost 5,000 pounds fully fueled with a warhead of almost one ton. The range of this version of the V-1 was just short of 150 miles.[2] (See Appendix A for a detailed description of the V-1 variants)



Source: USAF Historical Research Agency, (provenance unknown), V-1 general file, 1944, file #142.0423-8.

Figure 2. V-1 Flying Bomb

The launch preparation for the V-1 was very simple. The launch crew would load the V-1 on the launch ramp. The crew would then load aviation fuel into the fuel tanks. Next, the crew would attach the wings to the fuselage (detached wings facilitated transportation and storage). The crew would align the gyroscope to the ramp. The Germans constructed the ramp in the direction of the target. On receipt of final weather conditions, the crew would set the air log counter for the proper range to the target. Finally, the crew would attach the catapult to the missile for launch.

If the missile managed to successfully attain flight, it would proceed following the ramp heading. The flying bomb would normally fly below 3,000 feet at a maximum speed of 400 miles per hour. Once the bomb attained the preset range, the control surfaces would deflect to the maximum effect, tipping the missile toward earth. This maneuver normally resulted in choking the engine causing it to quit. The missile would impact the earth and detonate the warhead. Total flight time was a little over a half an hour.

The following items are peculiarities of the V-1 and deserve further discussion.

Pulse jet engine. The easily identifiable characteristic both visually and audibly about the V-1 is the pulse jet engine. The engine provided the thrust for the bomb and propelled it to the target. Its outward appearance strongly resembled a horizontal stovepipe. Air flowed through a series of vanes at the engine inlet. In the engine, the air mixed with aviation fuel and ignited. The pressure of the corresponding ignition forced the vanes shut at the inlet and forced the gases out the end of the engine. The inertia of the expulsion of gases pushed the V-1 forward. A corresponding negative pressure internal to the engine caused by the exiting gases resulted in the opening of the vanes. This cycle occurred approximately 500 times a minute. The cycling resulted in the characteristic "buzz" that gave the weapon its nickname.[3]

Navigation. The V-1 navigated to the targets simply. The missile maintained launch heading initiated by the launch ramp. There are no planned turn-points throughout flight. Corrections to flight path occurred if the bomb encountered side winds in flight. The most clever navigation aid was the air log. Basically, the air log was a propeller on the nose of the bomb. The air log counted the number of revolutions of the propeller during flight. Considering given atmospheric conditions (last update prior to launch), the crew calculated the number of propeller revolutions commensurate to range in miles. After attaining the number of revolutions, the system initiated bomb pitch-over.[4]

Launch system. The launch mechanism was the most complicated portion of the total weapon system. The launch system consisted of the ramp (looked like a ski jump) and the catapult system. The launch crew assembled the ramp on a concrete base pointed to the target 150 miles away. The catapult was a steam powered piston that accelerated the bomb to 15 g's resulting in initial flight velocity. This system was similar to the system currently used to launch aircraft off Navy carriers.

In summary, the Germans did not coordinate the development of the strategic weapons during World War II. Seeing the long range rocket as a technological extension of artillery, the Ordnance Branch directed the development of the V-2. Concurrently, the Luftwaffe was developing its own strategic missile, the V-1. The German High Command did not manage either service during the duplicative effort. This interservice rivalry resulted in two programs that did not meet their requirements. While the programs were a significant leap in technology, they drained vast resources from the country.

Notes

[1] Michael Neufeld, *The Rocket and the Reich* (New York, NY, The Free Press, 1995), 51.

[2] Dieter Holsken, *V-Missiles of the Third Reich* (Sturbridge, MA, Monogram Aviation Publications, 1994), 188.

[3] AC/AS Intelligence, Memorandum, Subject: German Pilotless Aircraft, (29 June 1944), 1-2.

[4] G.E.F. Proctor, A.I.2, Director of Intelligence, Memorandum, Subject: German Flying Bomb, Report No. 2246, (24 June 1944), 1.

Chapter 2

Operational Employment and Targeting Strategy

> *A complete breakdown of the social structure cannot but take place in a country subjected to this kind of merciless pounding from the air. The time would soon come when, to put an end to horror and suffering, the people themselves, driven by the instinct of self-preservation, would rise up and demand an end to the war.*
>
> —Giulio Douhet
> *The Command of the Air*

The German military lacked a specific operational strategy for the employment of the V-1 and V-2. Their hope was that the weapons would strike military targets precisely. The weapons would embody the need for a strategic bomber. Unfortunately, the V-1 was restricted to fixed launch sites pointed directly at the target. The V-2 rocket was never able to attain the lofty accuracy requirements. The Germans developed the strategy only after understanding the true weapons' capabilities.

Launch Sites

The range of each of the specific weapons determined the location of the launch sites. Initially, the V-1's range was approximately 150 miles. The location of their launch sites and corresponding ski ramps were along the French coast between Caen and Pas de Calais. These sites, originally, were permanent structures made of concrete attached to the facilities storing the bombs. Unfortunately, the structures were easy to identify necessitating attack by the Allies. The Germans then adopted less conspicuous launch sites. The launch sites consisted of steel ramps constructed on a concrete base surrounded by trees.

As the Allies marched across France following the invasion, the advance forced the Germans to abandon the V-1 launch sites. Aircraft were used as launch platforms for a period of time. The Germans constructed additional sites in Holland and Germany to continue attacks.

Initially, the Germans positioned V-2 launch sites in France. However, the Allies' advance and destruction of the sites forced the Germans to seek alternatives. The proximity of Holland to England offered them the next ideal launch location. There were no real fixed sites for the rocket similar as required by the flying bomb. The rocket was road transportable. All the Germans required was a flat surface normally surrounded by trees for camouflage.

The Germans heavily protected both the V-1 and V-2 sites with defenses. Anti-aircraft guns surrounded the sites, harassing low flying Allied aircraft.

Targeting Strategy

Artillery experience

General Dornberger and the Ordnance branch felt the V-2 was the next step in technology for artillery. He saw it as a long range "shell" capable of striking specific targets. He may have counted on an initial surprise factor for the weapon. However, the surprise would lessen and the Germans would use the weapon against specific military and industrial targets.

> Thus, in a fundamental sense the A-4 was another Paris Gun. It was the product of a narrow technological vision that obscured the strategic bankruptcy of the concept. The fact that Dornberger was also a space-flight enthusiast,…only reinforced his tendency to substitute technological enthusiasm for careful strategic thought.[1]

Italian General Giulio Douhet had postulated during the interwar years the devastating effect of tons of explosive, incendiary, and chemical bombs on a city. The destruction would have a significant impact on the morale of the nation. On the other hand, the Germans initially developed the rocket to strike military targets precisely. General Dornberger continued the development of the missile as an extension of the artillery.

Vengeance philosophy

The ultimate use and corresponding strategy for the weapons are attributable to Adolf Hitler. Following the Royal Air Force's night bombing attack against Lubeck in March 1942, Hitler wanted vengeance. The very name for the weapons, Vergeltungswaffen 1 and 2, translate to Vengeance Weapon 1 and 2. Hitler's thirst for retribution against the British drove his increasing the priority for their development and production. Defensive weapons did not interest him. He sought offensive weapons that could bring England to its knees. Throughout the rest of the war, he would devote the necessary resources for successful production of the vengeance weapons. The constant Allied attacks against German industrial and population centers further drove him for the need of revenge.

Although the Germans did not initially want to admit it, vengeance and revenge became the sole rationale and strategy for the flying bomb and rocket. After the Germans began attacks in June 1944, the Propaganda Ministry was careful to not use vengeance in its announcements. However, they soon abandoned this policy in hopes that vengeance attacks against England would improve the morale of the beleaguered German people.

Target selection

The need for revenge drove the initial target area for both weapons as London. As both weapons progressed in development and finally production, the weapons could not reach the accuracy requirements.

The Luftwaffe developed the V-1 with no real accuracy requirement. During flight tests from August through November 1944, the accuracy increased. Initially, only 17% of the flying bombs could hit a target circle of 19 miles diameter at operational range of 140 miles. By November, 46% could hit the same target circle.[2] Modifications to the missile and training of the launch crews resulted in the improvement. Near the end of the flying bomb campaign, the weapons were within a seven mile diameter circle after flying over 180 miles.[3] With such limited accuracy, one could select a target only the area as large as London. The actual impact of a V-1 on London could at times be miraculous.

There were several reasons for the lack of accuracy of this weapon. The primary reason was the inability to predict the direction and strength of wind along the flight path. The air log calculated range by counting the number of propeller revolutions on the nose of the bomb. Variations of wind being either too strong or weak would make the V-1 travel short or long respectively. Additionally, a combination of tolerances in the airframe during manufacturing and a gyroscope failure would lead to error. The simplicity of design that made the weapon so cheap also hampered the overall accuracy.[4] The first V-1 attack on June 13 is a further example of the lack of accuracy. Of the four missiles launched, one landed within 3 miles of the aimpoint, and the remaining three were no closer than 22 miles.[5]

Table 1 summarizes the targets and number of V-1's launched (both ground and air launched). The numbers in parentheses are the number of weapons that did not launch.

Table 1. V-1 Launch History

Target	Ground Launched	Air Launched	
England			
London	8839	1440	(1043)
Southampton	53	90	(9)
Manchester		53	
Gloucester		20	
	8892	1603	(1052)
Belgium			
Antwerp	8696		(1009)
Liege	3141		(366)
Brussels	151		(18)
	11988		(1393)

Source: Dieter Holsken, *V-Missiles of the Third Reich* (Sturbridge, MA, Monogram Aviation Publications, 1994), 248.

The Germans launched a total of approximately 22,500 flying bombs during World War II. Over half of the flying bombs launched flew to targets in Belgium (popular accounts indicate otherwise). Approximately 6% of all launches were unsuccessful.

General Dornberger had described the V-2's accuracy as 2 or 3 "mils." Translated to the operational range of 200 miles, this requirement was approximately one half a mile. Unfortunately, the actual performance of the rocket did not match the desired goal. At operational ranges, the V-2 could repetitively strike a target area with a diameter of 9.3 miles. The Germans even experimented with incorporating electronic beam guidance to point the missile to the target, but abandoned it with the threat of English jamming.

Due to the lack of accuracy, the Germans also utilized the V-2 as a terror weapon. On one specific occasion, they used the rocket to attack a military target. After the Allies successfully took the bridge at Remagen, they launched eleven missiles against the bridge. None of the missiles hit the bridge. Most of the missiles struck within two miles of the target. One missile landed forty miles short.[6] The reason for the extraordinary accuracy of these rockets is that the distance to the target from the launch site was only 140 miles. The proximity of the V-2 launch site to the target resulted in higher accuracy performance.

Table 2. V-2 Launch History

Belgium		**France**	
Antwerp	1610	Lille	25
Liege	27	Paris	19
Hasselt	13	Tourcoming	19
Tournai	9	Arras	6
Mons	3	Cambrai	4
Diest	2		73
	1664		
England		**Netherlands**	
London	1359	Maastricht	19
Norwich	43		
Ipswich	1	**Germany**	
	1403	Remagen	11

Source: Dieter Holsken, *V-Missiles of the Third Reich* (Sturbridge, MA, Monogram Aviation Publications, 1994), 245.

Throughout the course of World War II, the Germans launched over 3,200 rockets against the Allies. Similar to the experience with the V-1, over half of the missiles launched were against Belgium. Most of these strikes were against Antwerp and its ports. London, again, suffered the most from rocket attacks against England (consistent with the vengeance agenda).

Damage

Both weapons had a warhead weighing approximately 2,000 pounds. The V-2 warhead was the largest, weighing in at one ton. The V-1 warhead lessened in weight as the flying bomb range increased. The designers sacrificed warhead size to increase the amount of fuel carried.

The explosion of a V-1 was disastrous on the surrounding area. Impact fuses in the nose of the bomb detonated the warhead near ground level. When 1,800 pounds of explosives detonated, spherical rings of pressure expanded. The V-1 would reduce nearby brick buildings to rubble. Windows within a quarter mile radius of ground zero would shatter. The shock waves traveled at tremendous speeds leaving a vacuum in its wake. This vacuum could cause as much damage as the initial pressure wave.[7]

When compared to the flying bomb, the effects of the V-2 warhead are extraordinary. Not only did the rocket consist of a warhead weighing 2,000 pounds, but it also impacted the earth at supersonic velocity. The inertia of 5,000 pounds of metal impacting the earth could cause significant damage without the following explosion. The plan was for the fuses to detonate the warhead at first impact. However, the high speed caused the warhead to become buried several feet underground before detonation. Like the flying bomb, the shock wave would expand at tremendous speeds following detonation. The resulting destruction was devastating. Within a quarter mile radius, the explosion and overpressure would destroy most buildings. The impact and explosion would leave a 30 foot wide by 10 foot deep hole.[8] Witnesses to the attacks would compare the destruction to a gas main explosion.

Estimates on the destruction and death toll caused by the V-weapons is horrific. During a nine month period (June 1944 to March 1945), the weapons destroyed a combined total of 37,000 homes in England and Belgium. Additionally, they damaged approximately 1.5 million homes.[9] Finally, the weapons killed almost 9,000 people and wounded 25,000.[10] V-weapon attacks also impacted English industry. A significant portion of English armament production occurred within the borders of London. During the initial stages of V-1 attacks, non-essential personnel migrated out of the London area to the safer area north and west of London.

Battle Damage Assessment

The Germans were not able to determine the damage caused by the weapons. Reconnaissance flights over England were virtually non-existent. The lack of real-time intelligence forced the Germans to depend on their agents within England for information. The Germans resorted to reading the Obituary sections of the London paper to determine the location of deaths. The British soon restricted the amount of information portrayed in the paper. The Germans tried to use radar to triangulate the location of weapon impacts. Unfortunately, the accuracy of the triangulation data was within the actual accuracy of the weapons themselves. The British would eventually use the lack of German battle damage knowledge to their advantage.

The technical capabilities of both weapons paled to the initial need. Other than Hitler's fanatical desire for retribution against the British for civilian attacks, the Germans would not have produced the weapons. While the impact of either weapon could cause significant damage, the coordinated use never occurred. Vengeance became the only rationale for their use. The Germans ignored military area targets for attacks against population centers. They sought the results that Douhet postulated—an impact on the morale of the populace.

Notes

[1] Michael Neufeld, *The Rocket and the Reich* (New York, NY, The Free Press, 1995), 52.

[2] Dieter Holsken, *V-Missiles of the Third Reich* (Sturbridge, MA, Monogram Aviation Publications, 1994), 147.

[3] W.S.J. Carter, Air Defense Division, Supreme Hq. Allied Expeditionary Forces, Memorandum, Subject: Accuracy (31 March 1945), 2.

[4] Holsken, 141.

[5] David Johnson, *V-1 V-2* (New York, NY, Stein and Day Publishers, 1981), 42.

[6] Col W.S.J. Carter, Air Defense Division, Supreme Headquarters, Allied Expeditionary Forces, Memorandum, Subject: BIG BEN Attack on the Remagen Bridgehead (9 April 1945), 1-2.

[7] Johnson, 57.

[8] Research and Experiments Division, Ministry of Home Security, Memorandum, Subject: Warhead: Summary of Information on Effect (19 September 1944), 1-10.

[9] Holsken, 299-300.

[10] Major Bunn Hearn, Hq., US War Department, Memorandum, Subject: V-Weapon Activity Daily Report (7-8 April 1945).

Chapter 3

Allied Countermeasures

> *What is the object of defense? Preservation. It is easier to hold ground than take it. It follows that defense is easier than attack, assuming both sides have equal means. Just what is it that makes preservation and protection so much easier? It is the fact that time which is allowed to pass unused accumulates to the credit of the defender.*
>
> —Carl von Clausewitz
> *On War*

During June 1944, the Germans launched the first V-1 flying bomb against London. The British had intelligence during the previous year that the Germans were developing new weapons. They, in concert with the Americans, had conducted offensive operations against launch sites, production facilities, and transportation networks to lesson the threat. Additionally, after the attacks began, they developed a defensive scheme to defend England. Both offensive and defensive countermeasures were successful in reducing the volume of the attacks.

V-1 Flying Bomb

Offensive measures

After a V-1 flying bomb hit the Guard's Chapel at Wellington Barracks, General Eisenhower made launch sites the highest priority next to supporting the Normandy invasion. Eisenhower was sensitive to the morale of the English. His order diverted approximately 30% of the bomber force away from targets in the German industrial heartland.[1] This order continued the effort of offensive operations against V-1 launch sites. General Spaatz advocated continued attacks against German industry with concentration on the gyroscope manufacturing companies.

The Allies knew about the existence of the V-weapons since 1942. They had identified permanent launch sites in France by 1943. In December 1943, Eighth Air Force bombers attacked 24 known sites. Almost 700 B-17s dropped 1,400 tons of bombs on the targets. Later, they returned to drop an additional 3,000 tons of bombs on the targets. The attacks resulted in seven sites destroyed and fourteen others heavily damaged.[2]

Even the famous "dam busting" squadron participated on the attacks against the V-1 weapons. Number 617 Squadron of the RAF bombed V-1 storage sites in France during July 1944. After repeated attacks dropping a total of 2,165 tons of bombs, the squadron was successful in trapping several hundred flying bombs in their cave storage site.[3]

Despite the efforts of the Allied bomber and tactical forces, the Germans still managed to launch over 20,000 flying bombs against England and Belgium.

Defensive measures

The most successful countermeasure against the V-1 flying bombs came as defensive attacks. The combination of barrage balloons, fighters, and anti-aircraft artillery would destroy a majority of bombs before they reached their target.

First month. During the first month of the V-1 attacks, the fighters were the most successful at shooting down missiles. The English radar could detect the buzz bomb while it was still over water. The top speed of the bomb was around 400 miles per hour. The best performing Allied aircraft (Tempest V, Spitfire XIV, and Mustang III) were slightly better than that. The Allies would strip the fighters of the extra armor and tanks to increase performance. Additionally, the maintenance crews would polish the wings to gain as much speed advantage as possible. Intercepts would occur either during night or day. The V-1 was easy to identify during nighttime due to the pulsing ignition of the engine. The technique was to fly behind the bomb at a higher altitude. When the pilot was in range, he would initiate a dive and shoot at the bomb.

Attacks on V-1s were far from easy. Overtaking a flying bomb was difficult due to the close proximity of speeds of the aircraft and bomb. The flying bomb proved to be resilient to all but high caliber bullets. The steel sheet skin managed to deflect the normal caliber bullets carried on the fighters. The 20mm cannon proved to be the most effective gun, but required the pilot to maneuver closer to the V-1. Finally, shooting down a V-1 could be dangerous. If the pilot was unfortunate enough to hit the wrong part of the bomb, the warhead would explode showering the defending aircraft with shrapnel and flames.[4]

The pilots used another technique called tipping. In this maneuver, the pilot would pull along side the V-1. The pilot would bring the wing of his aircraft under the wing of the bomb and initiate a roll away from the bomb. The wings would contact and cause the V-1 to roll resulting in the tumbling of the gyroscope. Again, this maneuver did have its consequences. Since the flying bomb was made of steel skin and the intercepting aircraft wings were made of aluminum, the tactic could result in a bent wing for the fighter. Consequently, the British High Command outlawed this tactic for continued use.[5]

During this phase of defensive countermeasures, the fighters maintained a three to one advantage over the anti-aircraft operators.[6] The military established preliminary rules of engagement. The rules gave the fighters the perimeter layer of defense (over water and initial landfall). The anti-aircraft guns were next with the barrage balloons providing the last layer of defense. Additionally, the command restricted the defenders from intruding on the next layer of defense. Unfortunately, anti-aircraft gun operators might mistakenly fire upon a fighter or shoot down a V-1 for eventual impact in London.

Subsequent months. While the preceding tactics were successful at destroying approximately forty percent of incoming missiles, a large number were still impacting population centers. Also, the defenders needed new rules to minimize the fratricide. In July 1944, the British decided to rearrange the defenses. The new arrangement would position the Flak along the shoreline. The British split the fighters either side of the anti-aircraft gun belt. The barrage balloons maintained their position. Two technical improvements drove the movement of the anti-aircraft batteries. The first modification was the incorporation of radar and the anti-aircraft guns. Radar would point the guns to the target. The second improvement was the addition of proximity fuses in the anti-aircraft armament. By moving the anti-aircraft guns to the shoreline, the batteries had an unobstructed field of fire over the water.

By the first week of the new defensive scheme, the defenders shot down 43% of incoming V-1 missiles. By August, the numbers improved to 64%. By September, the updated defenses netted a phenomenal 83% of destroyed buzz bombs.[7] Prior to the change, the combination was responsible for 50 V-1 shoot-downs per week. After the change, the defenses accounted for 170 shoot-downs per week while the fighter force reduced from 180 to 120 aircraft.[8]

Near the end of V-1 attacks, the Germans launched 275 of the long range flying bomb. Of those launched, only 125 reached the English coast. From the remaining missiles, Flak operators shot down 87 while the fighters hit four. Only 13 of the remaining 34 bombs hit London.[9]

V-2 Rocket

Offensive measures

The only truly effective way to combat the V-2 was to destroy it prior to launch. The Allies conducted harassing attacks including strafing supply trains, suspected launch sites and manufacturing facilities. The first such attack occurred against the development and production facilities at Peenemunde in August 1943. This attack destroyed the missile production facility. The Germans continued to use Peenemunde as a research facility. However, the attack forced them to move the test launch facility to Poland and the production facility to within the Harz mountains in Germany. The crowning achievement of the attack was that the attack delayed production of missiles six months during the transfer.

Operation CROSSBOW was the code name for the offensive campaign against rocket sites and manufacturing facilities. High on the list of industrial targets were plants that manufactured liquid oxygen. Liquid oxygen was one of the two key ingredients needed for combustion in the engine. In December 1944, the British Air Ministry developed a list of eighteen manufacturing plants. The British felt the eight plants in Holland were the most important for targeting. Unfortunately, the Germans had located these plants within residential areas. The British were reluctant to strike these targets with strategic bombing.

In the long run, the British attacked only two German plants with little effect in the production of liquid oxygen.

The most success against the V-2 occurred by attacking supply trains with tactical aircraft. Locating the V-2 prior to launch was impossible. The missiles were very mobile and required minimum time between erection and launch. The Germans strove to launch the missile either the first thing in the morning or at dusk.

There is one account of a missile being shot down in flight. A formation of B-24 Liberators was returning to England after a mission when a V-2 passed between them. One of the machine gunners opened fire on the rocket and destroyed it. The rockets were sensitive enough that one 50 caliber bullet could puncture the skin and ignite the volatile fuel inside.[10] This example was one of a kind not repeated during the rest of the rocket campaign.

Despite the overwhelming amount of sorties and bombs dropped during Operation CROSSBOW, the V-weapons continued to rain down on England, France, and Belgium. From August 1943 to March 1945, the Allies flew 70,000 sorties and dropped 120,000 tons of bombs without halting the weapons.[11] The bombing sorties from August 1943 to August 1944 represented 14% of the total Allied bombing effort. Additionally, they flew 4,000 reconnaissance sorties representing 40% of the total sorties from May 1943 to April 1945.[12]

Defensive measures

Defensively, there was not much the Allies could do to stop the V-2 attacks. The missiles traveled at such great heights and at great speeds that shooting them down was impossible. Initially, the British thought the Germans used radio beams to guide the rockets to the target. They thought they could jam the beam and alter the rockets' flight path. The V-2 turned out not to use beam-riding guidance at all.

Deception

The English did partake in a deception campaign against the Germans. The Germans could not obtain accurate battle damage assessments for each weapon attack. Overflights of England by reconnaissance aircraft was hazardous due to British air superiority. The only method available to them was obtaining the information through their agents in England. Unknown to the Germans, the English had already turned their agents against them. The English knew the Germans were seeking accuracy information through electronic signal intercepts.

If one mapped the location of weapon impacts on London, a majority landed south and east (corresponding to landing a little short). The British wanted the agents to pass along that the weapons were impacting a little long (to the North and West). They hoped the Germans would compensate for the supposed error and correct further short. A debate developed within the British government on whether the deception should occur. Passing altered information might put innocent civilians in harm's way.[13] Over the course of the terror campaign, there is little evidence that the deception changed the targeting of the Germans.

In conclusion, the offensive and defensive countermeasures were successful at reducing the utility of both the V-1 and the V-2. Offensive attacks against V-1 launch and storage sites hampered unrestricted attacks against England and continental targets. More significantly, defensive measures significantly restricted the numbers of V-1s striking

London. The advent of radar-guided artillery with proximity fuses dropped V-1s hitting London to a trickle. Defending against the V-2 was nearly impossible due to its vast speed and height and limited flight time. The most successful countermeasure against the rocket was offensive strikes against production sites and transportation networks. For example, the Allied raid on the Peenemunde research and development station hampered V-2 operational fielding by at least two months.

Notes

[1] David Johnson, *V-1 V-2* (New York: Stein and Day Publishers, 1981), 59.

[2] Dieter Holsken, *V-Missiles of the Third Reich* (Sturbridge: Monogram Aviation Publications, 1994), 280.

[3] Memorandum, Subject: "Crossbow" Countermeasures: Progress and Intelligence Reports No. 43 (24 July 1944), 2.

[4] DMcK/JSS, Memorandum, Subject: Damage to Aircraft due to Attacking Flying Bombs (ORS 14/1/16, 5 August 1944), 2.

[5] Johnson, 82.

[6] Memorandum, Subject: Brief Report on Crossbow, (A.I.3, 23 July 1944), 10.

[7] USAF Historical Research Agency (provenance unknown), *Annex 1,* 13 July - 23 October 1944, file # 142.0423-27.

[8] Holsken, 292.

[9] Ibid., 295.

[10] Johnson, 168.

[11] Holsken, 285.

[12] Major C.R. Williams, *V-Weapons (Crossbow) Campaign* (US Strategic Bombing Survey, 24 September 1945), 3.

[13] Michael Howard, *British Intelligence in the Second World War, Volume 5* (New York: Cambridge University Press, 1990), 167-183.

Chapter 4

Assessment of Military Utility

> *The average error of both weapons amounted to more than 9.3 miles. Even if the Germans had launched one hundred twenty weapons per day, and we had not shot down any of them, their effect would not have exceeded the dropping of two to three one-ton bombs per square mile per week.*
>
> —Winston Churchill
> *V-Missiles of the Third Reich*

Several historians have claimed that the vengeance weapons could have changed the outcome of the war if the Germans had built or deployed them earlier. The weapons were very capable of causing destruction in the target area. They also caused a decrease in the morale of the targeted people. However, many factors contributed in the minor role the weapons would portray during the war.

Technology and Premature Deployment

The technology involved in the development and production of the V-2 was astronomical. Over a twelve year period, the Germans (specifically the Army Ordnance branch) were responsible in the leap of technology from small, solid rockets to liquid-propelled rockets capable of placing a 2,000 pound warhead 200 miles away. The advances in high speed aerodynamics, liquid fuel rocket propulsion, and gyroscope development far outpaced any other nation.

While the V-2 was technically advanced, the V-1 was the opposite. The Luftwaffe developed the flying bomb with simplicity, cost, and rapid development in mind. The shape of the weapon resembled a conventional aircraft. The most technologically challenging part of the buzz bomb was the pulse jet engine that provided the power. The classic example of its rudimentary design was the air log that utilized a propeller to calculate range.

However, both weapons suffered significant design problems at the time of their military deployment. The V-2 suffered a structural breakup problem during descent on the target. The missile had a tendency to explode in midair, showering the target area with shrapnel and a warhead. Additionally, a small minority of rockets never departed the launch area due to problems with the fuel system. The V-1 was plagued with even more pressing anomalies. Approximately, 25% of all V-1s launched never made it to the English coast. Some missiles crashed directly after clearing the ramp due to loss of engine thrust or minimum airspeed. Allied tactical aircraft could normally spot a camouflaged V-1 launch site by following the impact holes along a line past the ramp. Finally, the weapon at times proved to harass the friendly forces as much as the enemy. Occasionally, the gyroscope on the flying bomb would not function properly. The missile would fly in circles over the launch site until the air log initiated pitch over into the ground.

When the flying bomb campaign started in June 1944, the launch crews were far from able to meet the task. The goal was to have fifty-five launch sites ready for launch on the first day. However, Allied interdiction attacks had hampered the delivery of essential hardware. The attacks delayed the delivery of steel for the ramps and fuel for the V-1s. The Germans resorted to transportation by road during night.[1] After three days of nonstop work, the launch crews had assembled the missile and test fired the catapults. The invasion of the Allies forced the Germans to deploy the weapons before they had resolved all of the “ghosts” in the weapons.

Accuracy and Utilization

Neither weapon was accurate enough to strike military or civilian targets effectively. The original requirement for the V-2 was an accuracy of about a half a mile for a 200-mile range. The deployed and tested rocket was only able to reliably hit a target area of slightly greater than 9 miles. Likewise, the simple flying bomb suffered the lack of accuracy of about 12 miles over the operational distance. With accuracy figures as demonstrated, the performance forced the Germans to use the weapons to harass the enemy. The Remagen bridge attack was the classic example of using the wrong weapon for the right target.

Given the inaccuracy of the weapons, the Germans selected area targets. Regrettably, Hitler’s thirst for revenge limited the target list. The fact that the V-1 was dependent on a fixed launch ramp to determine flight direction further limited the targets available. Its simplicity negated the ability to fly a different course than one predetermined by the launch ramp. However, the Germans could assign different targets to the V-2. Except for the attacks on Antwerp, the Germans did not use the rocket to attack large logistic supply areas to hamper the advance of the Allies.

The Germans did not seem to use the weapons in a coordinated fashion supporting operational goals. Again, Hitler’s thirst for revenge against the British played too large a role. The Germans did not use the weapons to support the Battle of the Bulge campaign. Additionally, they did not use the V-weapons against the progressing Russians on the

Eastern front. The only strategy for their employment was to alter the morale of the English people.

Warhead

The warheads on the V-weapons were equivalent to two standard bombs carried on the Allied bombers. Given the previously stated inaccuracy of the weapons, different warheads may have been more effective. Some V-1s and most V-2s had a warhead consisting of Trialen. This material caused an explosion eight or ten times the strength of a normal explosive. The weapons really needed an atomic warhead to increase effectiveness. Unfortunately, the Germans were years away from developing this weapon of mass destruction. The Germans designed some of the V-1 variants to carry chemical or incendiary warheads. They never utilized these warheads during the war.

Italian General Giulio Douhet espoused the success of bombing cities with multiple weapons. The bombing campaign would cause the weakening of the morale of the attacked people. The V-weapon campaign effected the Londoners' morale. The Allies had just invaded the Continent in the beginning of June 1944. The Germans had not bombed London since the Battle of Britain in 1941. Although the war continued, the British were experiencing personal relief from the horrors of war. All of a sudden, the Germans broke the euphoria. The V-1 and V-2 attacks brought the war back to their front steps. It is conceivable that an orchestrated attack consisting of the weapons with chemical, explosive, and incendiary warheads would increase the depths of depression.

Cost Benefit Analysis

Several costs are associated with the two weapons programs. The first cost is the opportunity costs associated with defending against strikes and attacking the production, storage, and transportation of the weapons from Germany to the launch sites. The second cost is the overall cost of development and production of each of the weapons.

Opportunity Costs

By combating the possibility of V-weapon attack, the Allies encountered several hidden costs. These costs were an opportunity for the Germans. For example, after the V-1 flying bomb attacks started in June 1944, the British used day and night fighter squadrons to intercept the remote aircraft. During the initial stage of defensive countermeasures, approximately ten fighter squadrons defended London against attack.[2] These fighter squadrons supported defensive operations until the change in the defensive arrangements occurred in the middle of July. The defensive operations kept the aircraft from attacking potential targets on the continent.

The Allies expended a significant amount of energy attacking related vengeance weapons sites in support of Operation CROSSBOW. Operation CROSSBOW was the offensive attack of weapon manufacturing, storage, transportation, and launch sites. From August 1943 to March 1945, the Allies conducted massive bombing campaigns against targets located in Holland, France, and Germany. They flew around 69,000 sorties dropping 120,000 tons of bombs. During the period from August 1943 to August 1944, CROSSBOW sorties comprised 14% of sorties flown and 16% of total tonnage dropped.[3] These campaigns might have hampered the Germans, but did not result in cessation of the attacks. Again, the diversion of bombers away from normal daily operations presented an opportunity to the Germans.

Program Costs

The development of the strategic, vengeance weapons presented a significant cost to the German government. The Americans estimated the development cost of both development programs totaling about three billion dollars. Of this amount, the V-1 development costs were $200,000,000. The V-2 development program comprised an overwhelming majority of the costs. The Peenemunde test and production facility contributed to over two-thirds of the cost. Looking at the production costs, the Germans fabricated over 30,000 V-1 bombs at an average cost of 5,000 RM each. They also built 6,600 V-2 rockets at an average cost of 121,000 RM each.[4] Therefore, the entire weapons program cost the Germans a staggering four billion dollars.

The four billion dollar price tag did not bring a successful conclusion for the Germans. While it is true that the attacks impacted the morale of the English, they did not feel that defeat was near. The British conducted a study during the campaign comparing the V-2 rocket with the He-111 bomber. They concluded that the bomber could carry a larger payload (warhead equivalent), could deliver the ordnance more accurately, and was cheaper. The only drawback was that the bomber was more vulnerable.[5] The interesting fact about the analysis is that the British conducted the study, and the Germans did not. There is no evidence that the Germans ever conducted a parametric study of the cost benefit of either weapon.

The final statement concerning the cost of the programs deals with the sunk cost of lost missiles. Besides the significant number of V-1s the Allies shot down, almost a quarter of the flying bombs launched never made it across the English Channel. Although the V-1 was an order of magnitude less expensive than the V-2, the amount of money lost due to an immature design is incredible. At this stage of the war, the Germans could not afford the loss.

The possibilities for the alternative usage of the manpower and material allotted to the V-weapon development and production are outstanding. Both programs diverted the best engineers and technicians to solve plaguing technical problems. The Allies eventually destroyed the extravagant construction at Peenemunde and along the French coast during Operation CROSSBOW. This construction could have fortified the Normandy area instead. The vast underground production facilities in Nordhausen withheld space better spent on critical components. These facilities could have protected ball bearings, oil production, or aircraft production for Allied attack. The total construction of over 30,000 V-1s and 6,000 V-2s equated to 24,000 fighters. Additionally, the sheet metal used to produced the V-1 substituted the use on other priority programs. The 36,000 tons of explosives used on the weapons were not available for other munitions. During the end of the war, the Germans were substituting 70% “rock” salt as an extender for their munitions. Finally, the extensive Flak defenses of V-1 and V-2 launch sites restricted the available defenses around German cities. The number of heavy Flak guns around the V-1 sites in France equated to the number of guns protecting Hamburg.[6] While none of the alternatives would have won the war, the Germans could have prolonged the campaign. The lack of offensive weapons would have resulted in a defensive battle ultimately resulting in defeat.

Notes

[1] David Johnson, *V-1 V-2* (New York: Stein and Day Publishers, 1981), 36.

[2] Dieter Holsken, *V-Missiles of the Third Reich* (Sturbridge: Monogram Aviation Publications, 1994), 289.

[3] Major C.R. Williams, *V-Weapons (Crossbow) Campaign* (US Strategic Bombing Survey, 24 September 1945), 3.

[4] Holsken, 154.

[5] Johnson, 122.

[6] Williams, 34-36.

Chapter 5

Conclusion

> *The attacking air force may be equipped…with aerial torpedoes which can be launched from the ground and sent accurately toward their predetermined destinations; or with planes so silent that they cannot be seen or heard on the ground and so will pass overhead at high altitudes and go undetected.*
>
> —Gen. Hap Arnold and Ira Eaker
> *This Flying Game*

From June 1944 to March 1945, the Germans launched over 22,000 V-1 flying bombs and over 3,000 V-2 rockets against targets in England, France, and Belgium. The German strategy for these weapons was revenge, specifically against England, for the Allied bombing campaigns against German cities. The weapons never demonstrated the accuracy necessary to hold military targets at risk. Therefore, the only feasible targets were large area targets such as London and Antwerp.

Historians have claimed that with sufficient numbers or an earlier deployment that the weapons could have turned the tide of the war. Although the attacks affected the Londoner's morale, they were not close to total exhaustion. During the initial stages of the V-1 attacks, the government evacuated non-essential personnel outside the attack area. One must remember that the British had survived significant bombardment during the Battle of Britain without giving up hope. A portion of the despair felt during the vengeance attacks was due to the feeling that the war was almost at an end. Suddenly, Hitler was able to reach from almost ruin for one last swipe at England.

What was missing throughout the war, was a strategic vision—both for the desired end-state and weapons procurement. The German High Command allowed the services to separately develop weapon systems with little coordination. They performed no analysis to compare the benefits with the rocket, flying bomb, or strategic bomber with their associated costs. Four billion dollars would have gone a long way towards the purchase of strategic bombers capable of relatively accurate strikes against military targets.

The two weapons were significant developments to the history of warfare. The V-2 rocket would become the cornerstone of the United States strategic arsenal. The addition of a nuclear warhead contributed to its enhanced value. The space program and the strategic rocket forces of both the United States and Russia owe their existence to the German engineer who developed the V-2. The SCUD missile, used by Iraq in the wars against Iran and DESERT STORM, is a modern day example of the V-2. The SCUD basically differs little than its predecessor.

The V-1 flying bomb was the father of the modern cruise missile. The cruise missiles used during DESERT STORM (for example, the Tomahawk) incorporate significant improvements that make the cruise missile militarily significant. Due to the application of Global Positioning System information in the guidance systems, the modern cruise missile can threaten military targets with a similar warhead carried on the V-1. Additionally, the ability to change altitude, airspeed, and direction further enhance their survivability.

The Germans did not develop the V-weapons too late in the war to make a significant impact. They developed and deployed the weapons too early. Not until the advent of advanced guidance systems, computers, and atomic warheads did cruise and ballistic missiles become valuable in the modern world. The Americans and Russians fought the Cold War with missiles targeted against military and civilian targets. Additionally, Sadam Hussein tried to affect the morale of the coalition with SCUD attacks against Saudi Arabia and Israel. The V-1 and V-2 set the stage for future warfare, but were premature to change the outcome of World War II.

Appendix A

V-1 Characteristics

	A-1 Design	F-1 Design
Engine	Argus 109-104	Argus 109-104
Thrust	716 lb	716 lb
Empty Weight	1631 lb	1362 lb
Fuel Weight	1348 lb	2297 lb
Warhead Weight	1830 lb	1169 lb
Optimum Range	148 miles	200 miles
Service Ceiling	8840 feet	8840 Feet
Cruise Speed	360 mph	360 mph
Maximum Speed	408 mph	408 mph
Flight Duration	25 minutes	25 minutes
Warhead	Amatol 39A	Amatol 39A
Wing Span	17 feet 7 inches	18 feet 10 inches
Length	27 feet 1 inch	27 feet 2 inches
Height	4 feet 8 inches	4 feet 8 inches

Appendix B

V-2 Characteristics

Engine	18 Injection Cups (Direct Fuel Injection)
Thrust	60064 lb
Duration	70 seconds
Fuel	Alcohol and liquid oxygen
Dry Weight	8908 lb
Warhead Weight	2150 lb
Range	220
Altitude at Thrust	22-23 miles
Maximum Altitude	60 miles
Maximum Speed	3400 mph
Length	46 feet 1 inch
Diameter	5 feet 4 inches
Fin Span	11 feet 9 inches

Glossary

A-4	German nomenclature for the V-2 rocket
Meillerwagen	Transporter, erector and launcher for the V-2 rocket
NASA	National Aeronautic and Space Administration
RM	Reich Mark
V-1	Vengeance Weapon (Vergeltungswaffen) 1
V-2	Vengeance Weapon (Vergeltungswaffen) 2

Bibliography

Arnold, H. H. and Eaker, Ira C. *This Flying Game.* 2nd ed. New York, New York: Funk and Wagnalls, 1936.

AC/AS Intelligence. Memorandum. Subject: German Pilotless Aircraft, 29 June 1944.

Carter Col W.S.J., Air Defense Division, Supreme Headquarters Allied Expeditionary Forces. Memorandum. Subject: Accuracy, 31 March 1945.

Carter Col W.S.J., Air Defense Division, Supreme Headquarters Allied Expeditionary Forces. Memorandum. Subject: BIG BEN Attack on the Remagen Bridgehead, 9 April 1945.

Churchill, Winston. *Der Zweite Weltkrieg.* Stuttgart, Germany, 1949-1954. Quoted in Dieter Holsken, *V-Missiles of the Third Reich: the V-1 and V-2.* Sturbridge, Massachusetts: Monogram Aviation Publications, 1994.

Clausewitz, Carl von. *On War.* Edited and translated by Michael Howard and Peter Paret. Princeton, New Jersey: Princeton University Press, 1984.

Dornberger, Walter. *V-2.* Translated by James Cleugh and Geoffrey Halliday. New York, New York: The Viking Press, 1954.

Douhet, Giulio. *The Command of the Air.* Translated by Dino Ferrari. Washington, D.C.: Office of Air Force History, 1983.

Hearn, Maj Bunn, Headquarters, US War Department. Memorandum. Subject: V-Weapon Activity Daily Report, 7-8 April 1945.

Holsken, Dieter. *V-Missiles of the Third Reich: the V-1 and V-2.* Sturbridge, Massachusetts: Monogram Aviation Publications, 1994.

Howard, Michael. *British Intelligence in the Second World War, Volume 5 Strategic Deception.* New York, New York: Cambridge University Press, 1990.

Johnson, David. *V-1, V-2: Hitler's Vengeance of London.* New York, New York: Stein and Day Publishers, 1981.

Neufeld, Michael J. *The Rocket and the Reich.* New York, New York: The Free Press, 1995.

Proctor, G.E.F., A.I.2, Director of Intelligence. Memorandum. Subject: German Flying Bomb, Report No. 2246, 24 June 1944.

Research and Experiments Division, Ministry of Home Security. Memorandum. Subject: Warhead: Summary of Information on Effect, 19 September 1944.

USAF Historical Research Agency (provenance unknown), Annex 1, 13 July - 23 October 1944, file # 142.0423-27.

USAF Historical Research Agency, (provenance unknown), V-1 general file, 1944, file #142.0423-8.

US Strategic Bombing Survey, *Aircraft Division Industry Report*, 2nd edition, January 1947.

Williams, Maj C.R. Williams, *V-Weapons (Crossbow) Campaign,* US Strategic Bombing Survey, 24 September 1945.

Memorandum. Subject: Damage to Aircraft due to Attacking Flying Bombs, 5 August 1944.

Memorandum. Subject: Brief Report on Crossbow, A.I.3, 23 July 1944.

Memorandum. Subject: "Crossbow" Countermeasures: Progress and Intelligence Reports No. 43, 24 July 1944.

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